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The origins of the human remains from Perrins Ledge crematorium: strontium isotope ratio assessment of archaeological cremains

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THE ORIGINS OF THE HUMAN REMAINS FROM PERRINS LEDGE CREMATORIUM: STRONTIUM ISOTOPE RATIO ASSESSMENT OF ARCHAEOLOGICAL CREMAINS

by

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ABSTRACT

Strontium isotope ($^{87}Sr/^{86}Sr$) analyses have been used effectively to reconstruct the origin of osteological remains that have not been exposed to increasing temperatures (Bentley, 2006; Juarez, 2008; Knudson *et al.*, 2005). However, previous research has shown that no thermally induced changes occur to original strontium isotope values ($^{87}Sr/^{86}Sr$) of bone and teeth specimens that have been subjected to temperatures between 212 and 1832 degrees Fahrenheit (Beard and Johnson, 2000; Grupe and Hummel, 1991; Harbeck *et al.*, 2011), though the published literature regarding strontium isotope ratio stability and survivorship in thermally altered bone and teeth is limited. This is surprising given the potential implications for geolocation inquiries of cremains (or severely burnt remains) in both forensic and archaeological contexts. This research will focus on the latter context by using strontium isotope analyses, via thermal ionization mass spectrometry, to reconstruct the origins of human remains from a unique late Woodland period (A.D. 600-850) archaeological burial site known as the Perrins Ledge crematory, located in the lower Illinois River valley. Strontium isotope signatures derived from the Perrins Ledge cremains will be compared with values obtained from osteological faunal remains from three contemporary neighboring sites (Carlin, Apple Creek, and Newbridge). It is expected that the Perrins Ledge values will mirror those

derived from the neighboring contemporary habitation sites suggesting local groups used the crematorium.

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LIST OF ABBREVIATIONS

BU .... Boston University

CAA ....Center for American Archeology

ISM .... Illinois State Museum

Sr ....Strontium

TIMS .... Thermal Ionization Mass Spectrometer

CHAPTER 1

INTRODUCTION

Research Aims

The aims of this research project were threefold. First, to investigate the geographic origins of the thirteen individuals that were cremated at the unique late Woodland period crematorium known as Perrins Ledge located in the lower Illinois River valley. Second, to further explore the application of strontium analysis to thermally altered remains. Third, to contribute strontium isotope 87/86 signatures of the lower Illinois River valley to the isotope maps that characterizes the strontium values of the region. These aims were accomplished by testing the hypothesis that the crematorium was used by local groups residing at neighboring contemporary habitation sites as indicated by the results of strontium isotope analyses that showed signatures that mirror those derived from previously recovered faunal remains from three sites within 10 miles of the crematorium: Newbridge, Carlin, and Apple Creek.

Analyses of strontium isotope ratios ($^{87}Sr/^{86}Sr$) have been used effectively to reconstruct the origins of osteological remains that have not been exposed to increasing temperatures (Andrushko *et al.*, 2009; Bentley, 2004, 2006; Bentley *et al.*, 2001, 2004; Budd *et al.*, 2004; Buikstra *et al.*, 2003; Cox and Sealy, 1997; Eerkens *et al.*, 2014; Ezzo and Price, 2002; Ezzo *et al.*, 1997; Gregoricka, 2013; Grupe *et al.*, 1997; Hedman *et al.*, 2009; Kendall *et al.*, 2012; Knudson and Buikstra, 2007; Knudson and Blom, 2009; Knudson and Tung, 2011; Knudson *et al.*, 2004, 2005, 2007; Montgomery *et al.*, 2005;

Müller *et al.*, 2003; Price and Gestsdóttir, 2006; Price *et al.*, 1994, 2000, 2001, 2002, 2006, 2007; Slater *et al.*, 2014; Turner *et al.*, 2009; Wright, 2005). Studies have shown that light isotope ratios are significantly fractionated by thermal alteration (Grupe and Hummel, 1991; Harbeck *et al.*, 2011; Herrmann and Grupe, 1988; Schurr *et al.*, 2008). Therefore isotope ratios of the more commonly analyzed elements (i.e. carbon, nitrogen, and oxygen) cannot be assessed in bone or dental samples subjected to extensive thermal alteration because, before complete combustion of organic materials, the isotope ratios change as temperatures increase (Grupe and Hummel, 1991; Harbeck *et al.*, 2011; Schmidt and Symes, 2008). However, strontium isotope ratio ($^{87}Sr/^{86}Sr$) values remain unaltered in bone and dental specimens exposed to increasing temperatures of up to 1832°F (1000°C) (Beard and Johnson, 2000; Grupe and Hummel, 1991; Harbeck *et al.*, 2011).

The potential of strontium isotope analyses of cremated remains has been largely ignored and very few researchers have intentionally explored the application of strontium isotope analysis of previously thermally altered remains (Grupe and Hummel, 1991; Harbeck *et al.*, 2011). However, in recent months the number of studies in this area has increased (Graham and Honn, 2014; Harvig *et al.*, 2014; Snoeck *et al.*, 2015) and further work in this effort may result in progressive utility of this method in the many contexts where cremation or thermally altered remains exist. The current study offers the contribution of an additional analytical method to the limited number of methods currently available to assess osteological assemblages affected by the extensive damage caused by thermal alteration. Moreover, isotope signatures derived from this research will build upon strontium isotope signature maps (or isoscapes) (Figure 1.1). Such

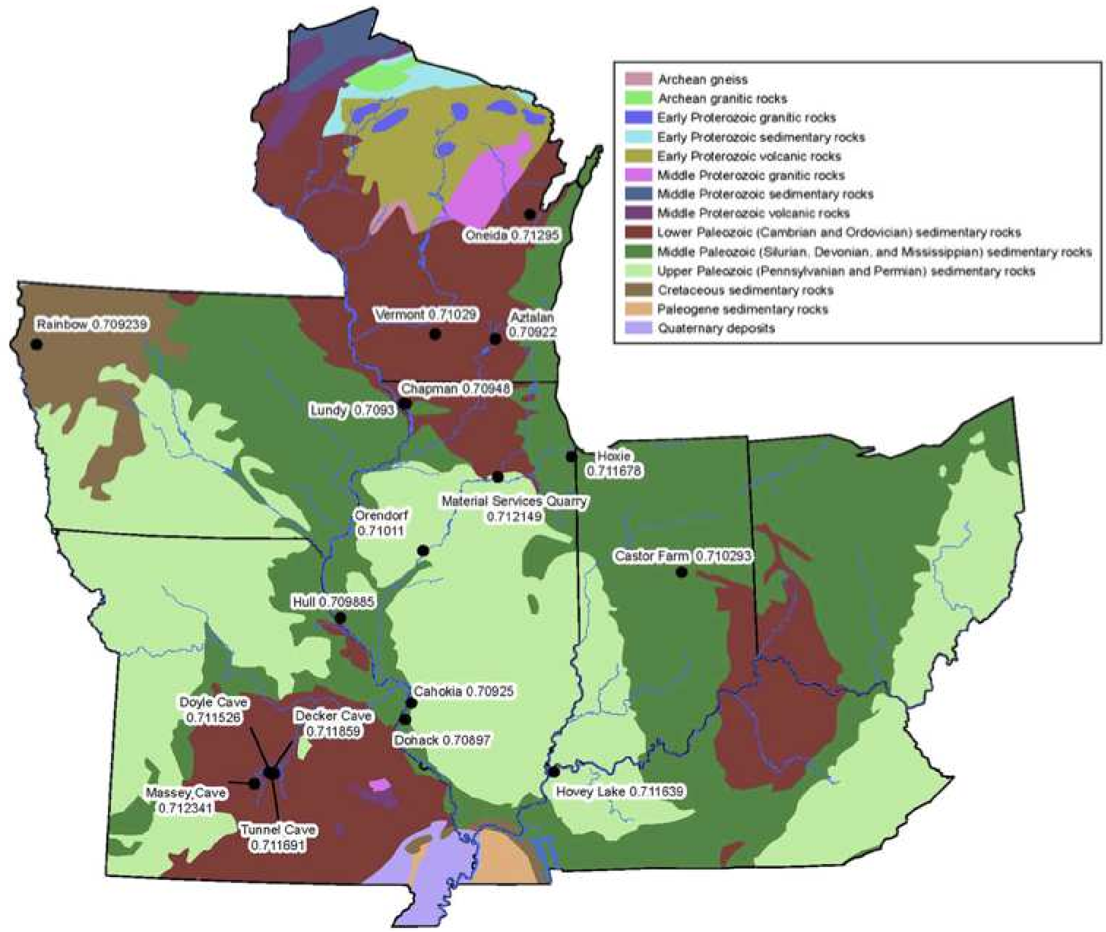

Figure 1.1 Map of bioavailable strontium signatures that characterize the isoscapes of the American Midwest derived from research in the region and compiled by Hedman *et al.*, 2009. (Hedman *et al.*, 2009; Price *et al.*, 2002, 2007). Taken from Hedman *et al.*, 2009:66.

efforts to characterize the isotopic landscape of the region can assist future research with goals to assess other strontium related migration and origin inquiries because these isotopic signatures are reference points that are temporally and spatially fixed and therefore can be used repeatedly to assess different questions. Perrins Ledge is a unique mortuary site given that in situ burning and burial is rare among sites of this region (Goldstein and Meyers, 2014) and the current project will provide invaluable insight into the complex mortuary practices of the prehistoric Late Woodland groups of the lower Illinois River valley.

The prehistoric Late Woodland archaeology of the lower Illinois River valley presents the opportunity to produce correlating data from both habitation and mortuary sites (Studenmund, 2000). This is ideal for strontium isotope analyses conducted to reconstruct the origins of individuals recovered from burial sites with proximity to contemporary habitation sites. Previous attempts to analyze light isotope ratios from Late Woodland period cremains of this region experienced the problematic fractionated values common in light isotope ratios exposed to increasing temperatures (Schurr *et al.,* 2008). Due to the fractionation resistant properties of heavier strontium isotope ratios ($^{87}Sr/^{86}Sr$) to thermal exposure, strontium provides a solution to previous problems in isotope analyses of burned human remains from sites in this region.

Perrins Ledge

Perrins Ledge Crematorium is a prehistoric Late Woodland mortuary site located two miles north of Kampsville, Illinois on the southern slope of a bluff in the Woods Creek Valley (Buikstra and Goldstein, 1973). It was excavated in conjunction with the Lower Illinois Valley Archaeological Program between late 1967 and 1968. Associated dating from artifacts recovered place the site in the early to middle Late Woodland period

(A.D. 600-850) (Buikstra and Goldstein, 1973). Burned human remains were recovered from the center eight foot by eight foot portion of the entire 20 foot by 20 foot structure of overlapping limestone slabs (Figures 1.2 and 1.3) (Buikstra and Goldstein, 1973).

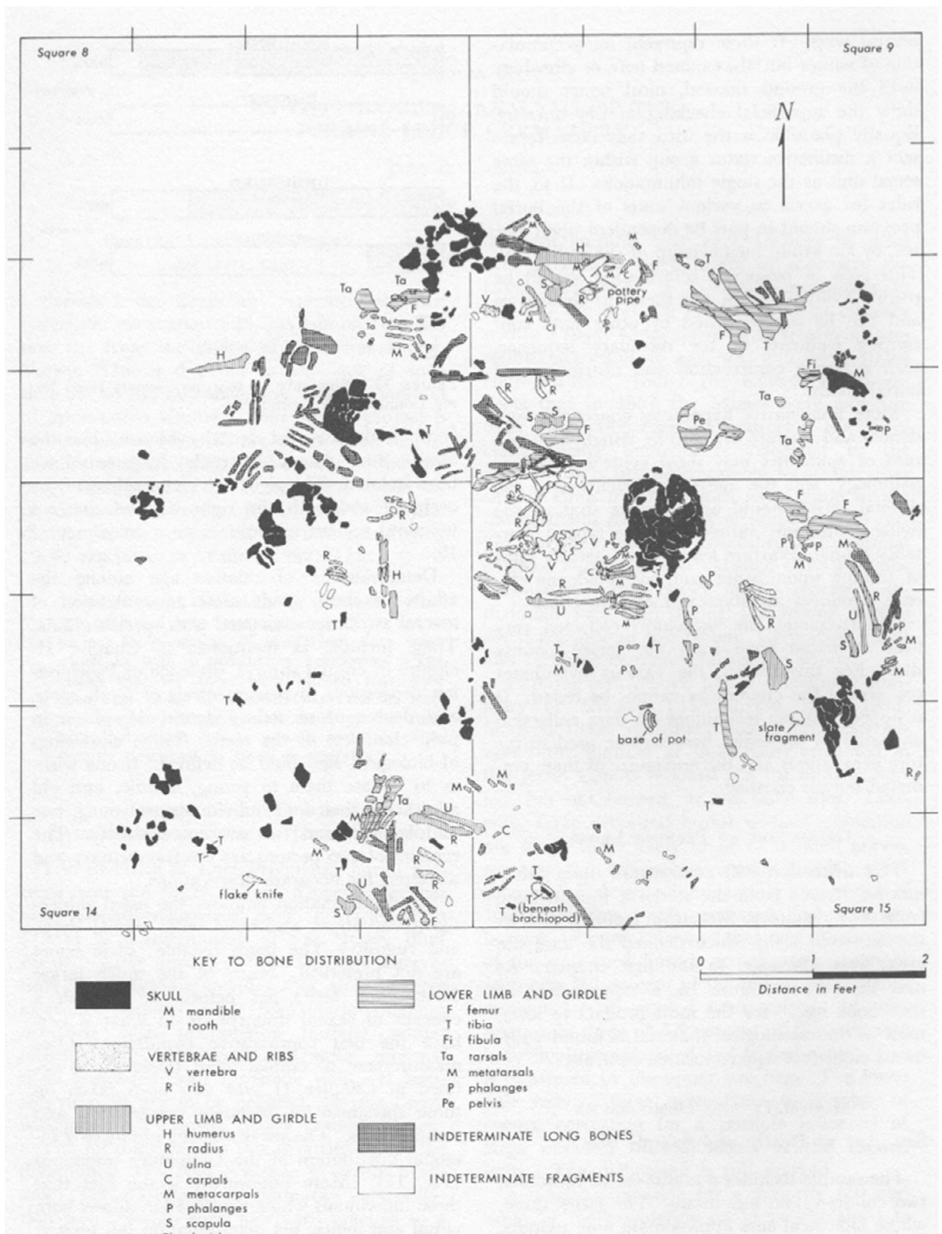

Figure 1.2 Overview map of distribution of recovered bone from Perrins Ledge Crematory. Image taken directly from Buikstra and Goldstein, 1973:26.

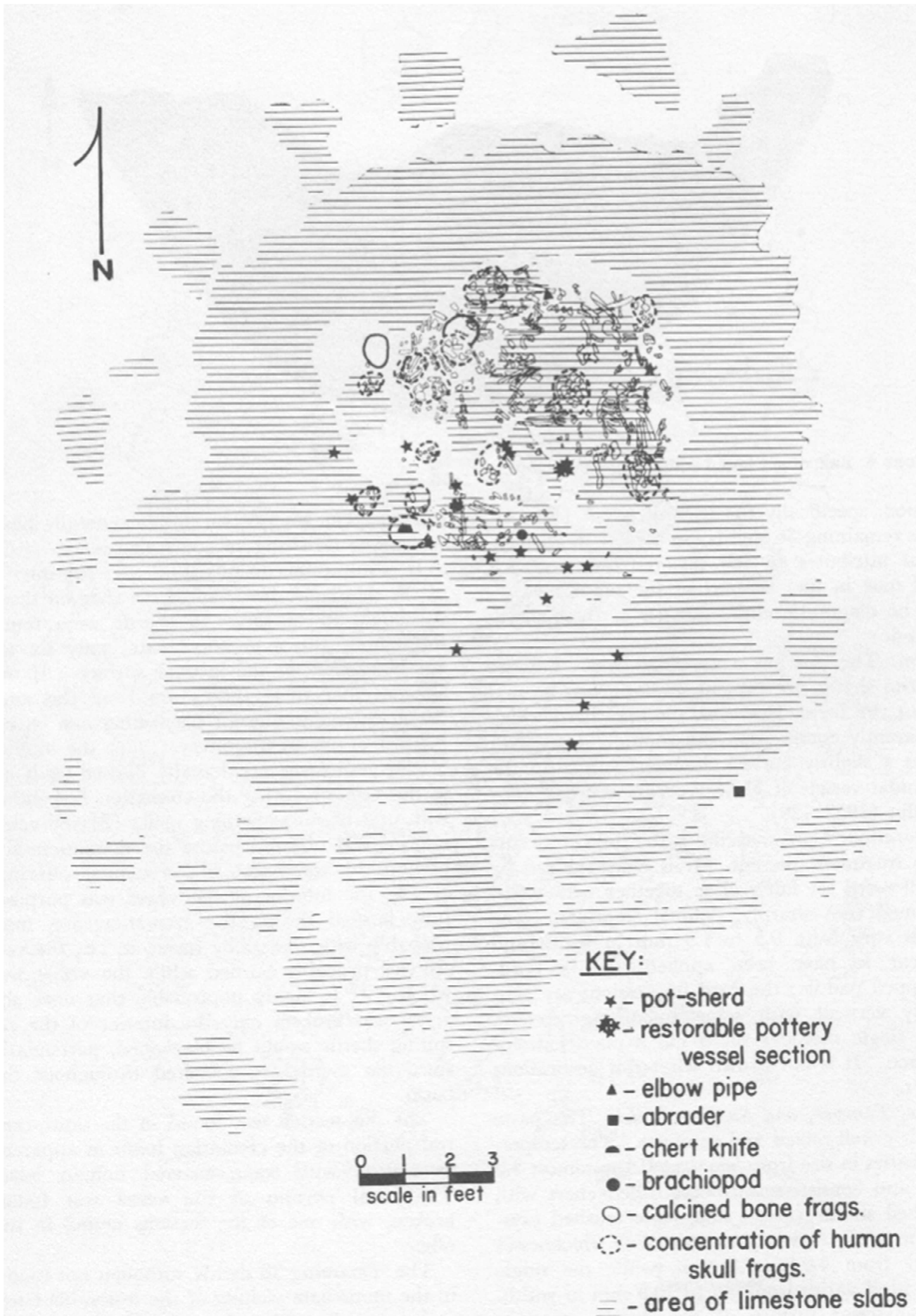

Figure 1.3 Overview map of the concentrations of bone, artifacts and limestone recovered from the Perrins Ledge site. Image taken directly from Buikstra and Goldstein, 1973:26.

Dr. Jane Buikstra performed the osteological assessment of the Perrins Ledge cremains in the early 1970's and determined the minimum number of individuals to be thirteen with an approximately equal number of males and females per adult age group including four young adults, two middle-aged adults, two older adults, two children, one infant, and two sets of adult human remains too fragmentary to assess sex or age with any degree of certainty (Buikstra and Goldstein, 1973). Scattered remains exhibiting both wet and dry burning patterns and differential burning patterns at the joint surfaces as a result of burning with adhering soft tissue while in articulation were recovered surrounding two individuals in situ that showed evidence only of wet burning. This was interpreted as evidence for at least two episodes of sequential burning and that fleshed individuals were placed in the crematorium, burned, and then moved aside to make room for subsequent cremation burning episodes of other individuals (Buikstra and Goldstein, 1973).

Despite the biological information determined from the remains, cultural affiliation was not previously determined. The few artifacts that were recovered from Perrins Ledge exhibit characteristics similar with those associated from a number of different contemporary nearby groups (Buikstra and Goldstein, 1973). However, at this time there are two hypotheses put forth by archaeologists specializing in the region as to which groups may have utilized Perrins Ledge. The initial hypothesis postulates that it was used by groups from neighboring contemporary habitation sites (Buikstra and Goldstein, 1973; Goldstein and Meyers, 2014), based primarily on proximity of those sites to Perrins Ledge. The other proposes it was used by non-sedentary hunter-gatherer groups who lived in widely dispersed homesteads (Schurr and Cook, 2014) and this is based on similarities between Perrins Ledge and other burned limestone tomb structures in the extended region. The current study uses strontium isotope analyses to test the hypothesis that Perrins Ledge Crematory was used by groups inhabiting local contemporary residential sites.

Strontium Isotope Analysis

Archaeological investigations of human population movement, or residential mobility, are most effectively addressed using a method that compares strontium isotope signatures between human skeletal remains and regional proxies (Bentley, 2006). The element strontium is an alkali earth metal that has four stable and naturally occurring isotopes: ^{84}Sr (0.56%), ^{86}Sr (9.86%), ^{87}Sr (7.0%), and ^{88}Sr (82.58%), defined by having a different number of neutrons than protons and thus different atomic mass (protons + neutrons). In residential mobility studies, strontium isotope signatures of a sample are measured by the abundance ratio of radiogenic strontium isotope ^{87}Sr, formed as a result of the decay of rubidium-87, to non-radiogenic isotope ^{86}Sr (Beard and Johnson, 2000; Bentley, 2006; Faure and Powell, 1972; Faure, 1986). Geological strontium signatures vary greatly within a region due to differences in the timing and processes of bedrock formation and its age and composition at the time of sampling (Beard and Johnson, 2000; Faure and Powell, 1972; Faure, 1986; Stueber, 1993).

As rock weathers it releases exchangeable strontium into the local environment that is transported and dispersed via wind and water systems and is considered bioavailable strontium once it is absorbed by local flora and ingested by local fauna (Bentley, 2006). Strontium contributes to skeletal samples via the food chain due to similarities between the atomic properties of calcium and strontium that allow the bioavailable strontium to replace some calcium in the mineral components of the bone and teeth of the consumer. Animals ingest strontium from a variety of resources within the perimeter of the foraging range specific to their species. Therefore animal remains can be used to calculate an average signature of the bioavailable strontium of a spatially defined region thus provide a baseline signature to which signatures derived from human skeletal samples can be compared (Price *et al.*, 2002). Given that living bone tissue remodels but dentition does not, samples of both can be compared in an individual with regional baseline signatures to assess residency, migration and mobility inquiries (Beard and Johnson, 2000; Bentley, 2006; Ericson, 1985; Slovak and Paytan, 2011). Ideally, dental enamel samples will reflect isotope signatures of the region in which that individual lived during dental development while bone samples will reflect the region occupied later in life.

Organization

This paper is organized as follows: Chapter Two focuses on the interpretations of prehistoric cremation as a mortuary practice and also briefly characterize the temporal, spatial, and cultural background of the prehistoric peoples of the lower Illinois River valley and surrounding region. The site summary and interpretations of the Perrins Ledge Crematorium, including the former osteological analyses of the Perrins Ledge cremains is also discussed in Chapter Two. Previous research contributing to the strontium isoscapes (isotope landscape maps) that characterizes the bioavailable strontium signatures of the region is also discussed including previous migration studies and the neighboring sites from which the baseline data is derived for this research. Chapter Three is a detailed explanation of the methods used in this study in the identification of appropriate collections, tissue procurement, clean-lab preparation of archaeological unburned faunal remains and cremated human remains samples in preparation for Thermal Ionization Mass Spectrometry, and the approach used to analyze, calculate, and compare the data sets. In Chapter Four the results of the analysis and data comparisons are presented including the data derived from the Perrins Ledge cremains and the faunal from the three baseline sites (Apple Creek, Newbridge, and Carlin). The implications of the results, the limitations of the methods utilized in this research, and suggestions for future research is discussed in Chapter Five including the potential of this work to continue to address prehistoric migration and trade inquiries in burned human and faunal osteoarchaeolgical assemblages and even origin reconstruction in contemporary forensic applications.

CHAPTER 2

CREMATION AND PERRINS LEDGE

Cremation in the Prehistoric American Midwest

The archaeological record of the American Midwest indicates that the mortuary behavior practiced between and within the many groups of the prehistoric peoples of the region is complex and varies greatly. Among the many burial modes, cremation has been previously interpreted to have occurred as a formal mortuary rite among all of the prehistoric groups in the Midwest from the Archaic to the Mississippian periods (Goldstein and Meyers, 2014). However, while inhumation was the primary burial mode across time among all groups of this region, cremation occurred most often among the archaic groups in the more northern parts of the Midwest. All of these examples exist as secondary cremation interred with secondary bundle and primary flexed burials (Goldstein and Meyers, 2014). Secondary cremation, in this context, can be thought of as a secondary deposit of remains previously cremated elsewhere.

The Riverside Archaic site (1000 – 400 BC), in northern Michigan is the earliest example of in situ burning and burial (primary cremation). Among the eight cremation pits recovered at the site, only two exhibited burnt surrounding soils and retained small elements that were lacking in those thought to have been moved from a previous location where the small elements were likely lost in the gleaning practices (Goldstein and Meyers, 2014). Another archaic cremation site in Wisconsin (Price Site III) exhibited basin-shaped burial pits with commingled secondary deposits of cremains and had either red ocher or limestone slabs marking graves. The cremains of these archaic sites show fracturing and burning patterns suggesting fresh burning on non-communal, individual pyres (Binford, 1963; Pleger, 2000). Overall, there appears to have been an increase in the number of cremations over time in the northern parts of the Midwest (Freeman, 1966). Goldstein and Meyers (2014) interpret the great variation in burning patterns at these sites as evidence for differences in timing and duration, and thus differences in the disposition of the individual cremated.

While evidence of cremation has been recovered from all archaic sites in the northern Midwest there is no evidence of cremation in the archaic components of lower Illinois River valley sites. There is, however, a slow development of formal cemeteries that occurred during the transition toward the middle archaic period. Even still, there is scarce mortuary evidence suggesting that social ranking existed during this time in this region except for the differential spatial distribution of bluff-top and contrasting below bluff cemeteries. This has been previously interpreted as evidence of differential treatment where lowland burials below the bluffs and at the periphery of habitation sites interred the old and disabled suggesting overall that bluff-top interments were maintained for productive individuals (Charles and Buikstra, 1983).

The following Early Woodland period (1000 – 150 BC) is known for the marked shift in the region toward an increase in social and economic complexity without the population aggregation or increase known to have occurred in the subsequent Middle Woodland period (Charles *et al.*, 1986). There are some examples from components of Early Woodland sites, such as Barnes Creek and Henschel, of highly fragmented and burned remains that were interred among bundle burials (Haas, 1996) but it is not certain whether these are a result of intentional cremation. The cremations that do exist in association with the Early Woodland period primarily consist of commingled secondary pit deposits of cremains with few non-elaborate grave goods.

Due to the elaborate cultural material, marked increased social complexity and population increase the Middle Woodland groups have been extensively studied. Burial mounds containing crypts and charnel houses begin to appear in the early part of this period. The Hopewell cultures of the Middle Woodland period (200 BC to AD 500) had expansive trade networks reaching well beyond the American Midwest, with groups participating in the exchange of goods and direct interaction most commonly along the major waterways (Struever and Houart, 1972). Evidence for differential treatment exists during this time in elite individuals buried within central mound features and accretional mounds contain most individuals of the society. Charles and Buikstra (2002) suggest that, within the Illinois Valley, this period reflects a shift from ancestor cult toward mortuary ritual. This is evidenced in the position and development of burial mounds suggesting the importance of community members as lineage groups due to resource competition and the use of ritual to control the struggle for resources and exchange ties between dominant kin groups with regional elite males. During this time there was marked population redistribution, increased emphasis on ritual, and effort to increase social standing (Charles, 1992; Charles and Buikstra, 2002). Cremation occurs less often during this time and most examples of it are similar to that seen from the previous period and have been recovered from Ohio where the Hopewell mounds are more exotic than in other regions (Baby, 1954; Goldstein and Meyers, 2014; Thompson and Jakes, 2005).

The shift to the late Woodland period (AD 400 – 1000) is defined by a greater emphasis on food production, although maize is not a staple until the latter half of the period, population dispersal, and mortuary practices are more variable than before (Buikstra and Milner, 1991; Goldstein and Meyer, 2014; Rose, 2008; VanDerwarker *et al.,* 2013). Cremation during this time is not common in the lower Illinois River valley. Much farther north late Woodland cremation burials were excavated from within oval and linear mounds built by the Effigy mounds groups but these do not indicate any differential treatment and it was not uncommon for burned human remains to be found within alters buried at the hearts of animal effigy mounds (Goldstein and Meyers, 2014).

Perrins Ledge Crematorium is a very unique late Woodland burial site located on a south-facing bluff overlooking the western Illinois River floodplain in the lower Illinois River valley. It is the only site in the region containing individuals who were burned and buried in situ. The floor of the structure was leveled prior to construction of the overlapping limestone slabs. The site consists of a 20 by 20 foot limestone structure with a concentration of the remains of 10 adults of both sexes, two children (a seven and a nine year old), and a nine month old infant, commingled within the middle eight by eight center of the structure. Radiocarbon dating places this site at around AD 600-850 which is consistent with the associated dating from recovered artifacts that include ceramics, an internally scorched and partially fragmented ceramic bowl, lithic debris, a scraper, a knife, and a pipe stem (Buikstra and Goldstein, 1973; Goldstein and Meyers, 2014).

Interpretations of the site and remains suggest that there were two episodes of burning and the initially burned group was swept aside to make room for the second group found in situ. Goldstein and Meyer (2014) suggest that Perrins Ledge may have been a crematory processing site where remains were later transported and buried as secondary deposits in another cemetery location.

During the post late Woodland Mississippian period, cremation was not the primary burial mode, appearing at only two excavated sites of this period. Of particular interest to this research are the burned human remains excavated from the second level of a platform mound from a large northern Mississippian village site known as Aztalan. Initially, interpreted as a crematory (Rowe, 1958), later interpretations of this excavated feature suggest it was a charnel house that may or may not have been intentionally burned (Brown, 1979; Goldstein, 2010). These burned remains were sampled among many other unburned remains from this site as part of a larger question answered with strontium isotope analysis and the results suggested that the burned individuals were nonlocal, likely from the Cahokia region (Price *et al.*, 2007). It should be noted that, to the knowledge of the present author, that this is the first known application of strontium isotope analysis to prehistoric burned human remains. Whether this was performed intentionally or not, the publication of this work does not give any indication or mention acknowledgment of this fact suggesting it may have been inadvertent. However, initial reports of the charnel house assemblage describe that the remains were very calcined (Rowe, 1958) and therefore it can be assumed that the sample from which the strontium signatures were derived were also calcined, although Price and colleagues (2007) do not discuss the extent to which the bone was burned.

Previous Interpretations of Prehistoric Cremation

It is not surprising that archaeological evidence suggests that multiple types of prehistoric cremation existed (Byrd *et al.*, 2012; Creel, 1989; Gilman, 1990; Goldstein and Meyers, 2014; Hegmon, 2002; Mabry, 1998; Rakita and Buikstra, 2005; Reinhard and Fink, 1994; Thompson, 2014; Wills, 1988) given the amount of variation within the same mortuary practice between contemporary groups (Beck, 2005; Brew and Huckell, 1987; Goldstein and Meyers, 2014; Kroeber, 1927; Riley, 1975). Mortuary behavior consists of, not only the physical methods involved in disposal of the dead, but includes rituals performed by the living that are defined by group ideologies and the restructuring of parts of the social system affected by the death of an individual of that system.

The use of ethnography is important to consider when attempting to interpret mortuary behaviors of the past, however very little ethnography exists for cremation practices among Native American groups in regions of the United States beyond the American Southwest. Archaeological analyses of mortuary behavior of prehistoric peoples, without ethnographic comparisons, are limited only to interpretations made from material culture. While this has been done by archaeologists studying prehistoric native groups of the Midwest, primarily because of the lack of ethnographic works regarding cremation within that region, a comparison between interpretations of cremation as a mortuary practice derived from those studying the American Southwest region with access to rich ethnographic and archaeological records of cremation, may lend some insight into prehistoric cremation as a mortuary practice. Obviously, the leap from the American Southwest to the prehistoric Midwest including the temporal gap between historic and prehistoric groups in the Southwest, is great and it is presumptuous to assume that any of those groups performed the same practice for exactly the same reasons, especially considering the aforementioned observed variation between contemporary historic groups alone. However, the use of ethnography with archaeological evidence is crucial for encompassing the broad range and scope of cremation as a mortuary practice within and between groups.

Although ethnography is important to consider, some components of archaeological evidence can be incredibly informative independent of ethnography. This is evident in the limited discourse of interpretations of the practice of cremation in the Midwest between Midwestern archaeologists (Baby, 1954; Goldstein and Meyers, 2014; Goldstein, 2010; Hertz, 1907; Rakita and Buikstra, 2005; Rowe, 1958). Archaeological materials, that have survived the elements, represent a subset of the tangible components of the culture being investigated. That small amount of evidence can be enough to characterize and determine intentional action. But the ideas and thoughts driving past intent are temporally unattainable. Unlike physical materials, abstract components of past cultures, such as thought, do not survive the death of the individual. Basic intent can be inferred but reasons behind the intent are much more elusive. For example: taphonomic interpretations of bone as intentionally fractured cannot always exclusively explain why the intent was to fracture the bone without comparing with ethnographic accounts and/or osteoarchaeological assemblages.

Anthropological discourse has warned to approach comparisons with caution when attempting to interpret prehistoric mortuary behavior from ethnographic accounts, especially cross-cultural comparisons (Bartel, 1982; Ucko, 1969) for the reasons previously discussed. However, considering that the bulk of the present study weighs most heavily upon the strontium isotope results the following information is presented in order to provide insight into cremation as a mortuary practice. Direct interpretations of prehistoric behavior from historic accounts of cremation in the American Southwest were avoided in this study but previous interpretations of prehistoric cremation as a mortuary behavior is presented. Reasons behind the behaviors resulting in such evidence described in the ethnographic record will also be presented but does not imply the same reasons existed for different prehistoric groups.

As previously mentioned, cremation as a mortuary practice has been studied more extensively among historic and prehistoric groups of the American Southwest due to the wealth of comparative information from recovered artifacts and the rich ethnographic record of that region. Although there is great distance between native groups of the American Southwest and those in the Midwest they are temporally parallel. However, only broad comparisons can be made when referring to the American Southwest in Midwestern contexts regardless of temporal similarities especially considering dissimilarities in the recovered material culture in regards to cremation. It is well documented that Middle Woodland groups in Illinois participated in an expansive trade network. Whether this trade network could have contributed to cultural diffusion and the spread of mortuary customs between the American Southwest and the Midwest seems reaching. However, in consideration of the human condition as a whole, symbolisms of cremation as observed ethnographically among Native American groups may shed some light on potential mortuary behaviors of the past even across great distances.

Some archaeologists studying cremation in the American Southwest have made previous interpretations derived from archaeological data and ethnographic literature that provides some indications of cultural continuums and possible lineage ties between non-contemporary groups which is further backed by linguistic studies, despite ongoing debates on the possibility to suggest cultural continuums (Bartel, 1982; Ezell, 1963; Ucko, 1969). This simply suggests that the interpretations of cremation in this region from comparisons of ethnographic literature and the archaeological record may have some solid ground. Regardless, even without a rich ethnographic record of cremation linking the recovered material culture in the American Midwest prominent archaeologists have made convincing arguments of interpretations of the practice of cremation in the region. The following interpretations allow for generalized meanings to be drawn from the overall scope of cremation as a mortuary practice.

Randall H. McGuire (2004), while focusing on the cremation practices from ethnographic accounts and archaeological evidence of the historic California and Arizona Yuman groups, asserts that the cremation ritual is more complex than a simple expression of the social persona of the deceased. He asserts that it is an integral part of the processes that create and maintain primary social relations between groups that define both family and extended family lineage and that functionally organize the framework of social relations. He infers that mortuary ritual is performed to reallocate and confirm power and relationships between the living that are associated with the deceased, both between and within immediate groups. That the practice of grave goods being offered to be burned with the body from individuals of outside groups represent keeping track of debts owed and paid which negotiate relationships between interacting groups. Essentially, cremation served to restructure intergroup and intragroup social dimensions affected by the death of an individual with branching social ties and potentially any social or economic unfinished business at the time of death (McGuire, 1992).

Where social structure is arguably maintained through cremation ritual some suggest that this is, in part, due to the processes of ancestralization expedited by the act of cremation (Gordon and Buikstra, 2005; Williams 2008). Gordon Rakita and Jane Buikstra (2005) discuss how the Native American belief systems include spiritual entities of the dead that can travel to and from the supernatural and physical world. They suggest that cremation acts to release the soul from the body in this world as a transformative process from life to death. It further acts to create a smooth transition into the supernatural world by completing the transformative process through the creation of a spiritual entity (Rakita and Buikstra, 2005). They contend that cremation symbolizes the separation and removal of the supernatural from the physical world. That the act of cremation, that serves to halt the natural processes of decomposition, also serves to halt the decomposition of social structure when a death occurs within a group. Complete transition from the physical to the natural world as created by cremation is a complex and continued interaction between the living and the dead. Decedents continue to affect and maintain social relationships among the living in the form of ancestors of surviving descendants. Additionally, Howard Williams (2008) proposes that the many rituals beyond just the act of igniting the remains include uses of fire in rituals intended to commemorate the dead. He infers that the primary goal of the act of cremation is the thorough and rapid transition from death to the ancestral state.

M. Scott Thompson (2014) suggests that transformation via cremation, from the body into a spirit, is a performative event. Participation in the form of observing the act of cremation allows the observers to view the destruction of the body. This visual participation in effect, provides the conceptualization of the physical transmutation of the dead into another being by the observer. Thompson also lends some insight into the spatial patterns of cremation deposits (2014). That the proximity of secondary cremation deposits to homes or activity spaces of the living can reflect the perspective held by the group of the want to either distance themselves from the spirits of the dead or keep them near.

In her examination of the cremation practices among the Hohokam of the prehistoric American Southwest, Jessica Cerezo-Roman (2014) discusses potential reasons for what may be interpreted as differential treatment within groups of children. She suggests that it is likely that the inhumation of neonates and infants as a preferred method over cremation is due to those individuals not reaching the age that is social defined for completed identity or personhood. Differential treatment seems to appear often in relation to cremation practices in the archaeological and ethnographic records.

Variation of cremation vessels types recovered from the same period and associated with different architectural structures within a site has been suggested to be due to horizontal differential treatment (Byrd *et al.*, 2012). Simultaneously occurring inhumation and cremation at different relative frequencies has been considered to be due to vertical differential treatment which is not exactly supported by the ethnographic record that discusses the use of cremation under unusual circumstances (Underhill, 1939). Crown (1990) warns that due to the destructive nature of cremation of the body and associated burned artifacts, and the practice that includes secondary deposits of cremains, assessment of social status of cremains is difficult.

Spiritual components to cremation exhibit an overall clear interaction between the living attempting to instate control over the fearful supernatural powers of the dead; supernatural powers that may have been a reflection, in part, of their limited knowledge of the spread of disease. This is potentially reflected in the fear that spirits of the deceased would come back to the home to cause illness. Consider, the Papago belief that spending too much time thinking of the deceased could, in itself, cause illness: perhaps the same illness that lead to the death of the individual on whom they meditate? Some illnesses take several days to exhibit symptoms in those that may have had contact with the deceased prior to death while likely very contagious. Not understanding the true mechanisms of the spread of disease might solicit responses of community members to assume the mourner was simply dwelling too much on the loss of the loved one, which also can be misconstrued for depression that may appear as an illness as well. Some forms of mourning in modern culture include holding on, sometimes literally, to personal items having once belonged to loved ones who have passed, in order to memorialize them in some way or attempt to avoid their loss. But if that person had some illness that can be transferred across tangible mediums, such as bacteria and resilient viruses that would be prevalent on the personal items and on many surfaces of the homes of the sick, then it would not be surprising if an association with burning infected personal effects and homes of those that died from illness may develop over time unknowingly as a genuine method of preventing contagion. Spier (1933) alludes to the possibility of an element of the spread of disease being slightly understood by the Yuman groups that would cremate in some cases to eradicate illness of the deceased, which also implies an unspoken understanding of potential disease and possibly disease associated with putrefaction.

It is well known, however, that contact with other communities can spread disease. This may have influenced the Piman and Papago practice of cremating individuals that died on enemy territory to halt spells from enemy magic. Much of the understanding and use of magic is a supplement to knowledge of actual processes. Disease had to have been profoundly involved in magic ritual, therefore it would not be surprising if enemy magic included spells that caused illness when in fact contact with outside groups was the culprit of disease spreading agents.

It is not a new idea that burning personal items of the dead may have served to transport those items to the land of the dead incarnating them into supernatural incorporeal versions of their earthly forms. The archaeological record is littered with what is commonly referred to as ritually ‘killed’ vessels and broken associated grave goods (Reinhard and Shipman, 1978; Haury, 1976). Dubois (1907) describes metal knife that had been broken in half that was included as a burial good within a recovered Diegueno cremation vessel. It has been suggested that the grave goods are broken to release the spirit of the item to be allowed to transform and accompany the deceased to their journey to the land of the dead.

Social implications for cremation include the need to restructure social ties to accommodate the void presented by the death of an individual of the community in communities that likely distributed occupational positions based on efficiently functioning social structures. A cremation ceremony gathering of the community and friendly neighboring groups allows for the greater social sphere to become aware of the void presented by the death of an individual within that social structure therefore allowing an expedited process of social restructuring.

Although it is likely that universal cross-cultural components of the mortuary practice of cremation exist, the contexts of the Perrins Ledge Crematorium are very different from those recovered from the American Southwest. Drawing reliable interpretations of the meaning of cremation as a mortuary practice from Perrins ledge is more problematic than interpretations derived from sites in the American Southwest. Especially, given that the ethnographic record of mortuary behavior is scant in the American Midwest and that the origins of the individuals recovered from Perrins Ledge Crematorium had not been previously known. Without an ethnographic record, the value of the information provided by reconstructing the origins of the Perrins Ledge individuals is elevated considering that it may be associated with a known group with other forms of established mortuary contexts recovered from the local region to which Perrins Ledge can be contrasted and compared. Buikstra and Goldstein (1973) were able to extract an astonishing amount of information from their investigation of the Perrins Ledge Crematorium, effectively altering the commonly held view among archaeologists of the time that the evaluation of cremation sites were not worth the effort. Since their investigation of Perrins Ledge in the early 1970's, new methods, specific to assessing cremains, have been developed and show reliable utility although hints of dismissive attitudes toward cremains persists (Schmidt and Symes, 2008). This is not surprising due to the overwhelmingly destructive effects of thermal alteration to skeletal remains. The present study provides work toward the effort to alter the dismissive view of cremation assessment and it illustrates that strontium isotope analyses can be used to accommodate previous investigations of prehistoric cremation. The present study also demonstrates that strontium isotope analyses are able to reconstruct the origins of individuals from skeletal remains that exhibit the extensive damage of exposure to thermal temperatures great enough to cause complete combustion of organic materials and extensive fragmentation.

CHAPTER 3

MATERIALS AND METHODS

Baseline Data Collection

Faunal remains collections containing procurable skeletal tissue samples (bone or teeth specimens) from at least five separate small-bodied non-human mammals from three previously excavated archaeological sites, were identified for their utility for deriving meaningful baseline data. The three habitation sites chosen for this study are housed at the Illinois State Museum in Springfield, Illinois, and include Carlin (11C124), Newbridge (11GE456) and Apple Creek (11GE2) (Figure 3.1), chosen due to their physical ($\leq$ 10 miles) and temporal proximity to the Perrins Ledge Crematorium. It is hypothesized that the prehistoric groups occupying Carlin, Newbridge and Apple Creek during the late Woodland period used Perrins Ledge Crematorium to cremate their dead. Carlin and Newbridge were both occupied during the late Woodland period (Asch and Asch, 1978, 1981) and Apple Creek contains a late Woodland component from which the baseline faunal samples were derived (Buikstra and Goldstein, 1973).

Non-human mammal remains of taxa associated with small foraging ranges were carefully selected from the Newbridge, Carlin, and Apple Creek site assemblages to maintain narrow average ranges of the bioavailable strontium signature of the region containing each respective archaeological site. Enamel was preferred to bone or dentine specimens due to the resistant properties of enamel to diagenetic alteration (Bentley, 2006). However, when the available enamel specimens that fit the criteria of this study were exhausted, bone, tiny whole teeth, or tooth fragments that included portions of dentin were used. Previous research has shown that meaningful bioavailable strontium signature ranges can be effectively calculated for baseline data of a site using multiple specimens derived from a combination of tissue types including enamel, dentine and bone tissue in strontium isotope investigations (Slater *et al.*, 2014). The Newbridge, Carlin, and Apple Creek specimens were transported from the Illinois State Museum, on-loan, to the Boston University Forensic Anthropology clean lab for tissue procurement.

The following indicates the specific species and tissue types associated with the procured specimens used in this study from the faunal assemblages of each of the three baseline sites (see also Table 3.1). For deriving the baseline signature range for Apple Creek, enamel from one individual identified as *Ictidomys tridecemlineatus* (13-lined Ground Squirrel), enamel from one individual identified as *Sylvilagus floridanus* (Eastern Cottontail), a crushed molar from one individual identified as *Mustela vison* (Mink), and enamel from two different individuals identified as *Urocyon cinereoargenteus* (Gray Fox) were used. The species and tissue types used to derive the baseline signature range for Newbridge include a crushed molar from one individual identified as *Sciurus niger* (Eastern Fox Squirrel), enamel from one individual identified as *Ondatra zibethicus* (Muskrat), enamel from one individual identified as *Sylvilagus floridanus* (Eastern Cottontail), bone from one individual identified as *Microtus* spp. (Vole), and bone from one individual identified as *Scalopus aquaticus* (Mole). For Carlin, the species and tissue types of the specimens used for the baseline data include enamel from one individual identified as *Orozomys palustris* (Marsh Rice Rat), bone from one individual identified as *Sylvilagus floridanus* (Eastern Cottontail), enamel from one individual identified as

Ondatra zibethicus (Muskrat), and enamel from two different individuals identified as *Marmota monax* (Woodchuck).

Table 3.1 Taxonomic classification of archaeological specimens used to derive baseline data.

Specimen	Taxonomic Classification	Common Name	Source
425b	*Ictidomys tridecemlineatus*	13-lined Ground Squirrel	Apple Creek
341b	*Sylvilagus floridanus*	Eastern Cottontail	Apple Creek
F267c	*Mustela vison*	Mink	Apple Creek
600	*Urocyon cinereoargenteus*	Gray Fox	Apple Creek
151	*Urocyon cinereoargenteus*	Gray Fox	Apple Creek
121C-W	*Sciurus niger*	Eastern Fox Squirrel	Newbridge
129C	*Ondatra zibethicus*	Muskrat	Newbridge
120B	*Sylvilagus floridanus*	Eastern Cottontail	Newbridge
113B	*Microtus* spp.	Vole	Newbridge
117C	*Scalopus aquaticus*	Mole	Newbridge
101-3.1	*Orozomys palustris*	Marsh Rice Rat	Carlin
101-3.2	*Sylvilagus floridanus*	Eastern Cottontail	Carlin
60-2	*Ondatra zibethicus*	Muskrat	Carlin
9-1	*Marmota manox*	Woodchuck	Carlin
101-3	*Marmota manox*	Woodchuck	Carlin

Perrins Ledge Collection

The human remains from the Perrins Ledge Crematorium (CAA project # 280) are housed at the Center for American Archeology in Kampsville, Illinois. Procurement of the Perrins Ledge Crematorium specimens used in the study, took place on site at the Center for American Archeology repository lab in the summer of 2013. Bone tissue samples were procured from the posterior medial aspect of ten fully developed right petrous portions of the temporal bone and dental tissue samples were extracted from the teeth enamel of five adults and three subadults totaling 18 specimens representing 13 individuals. Table 3.2 shows the approximate age range of crown development for the Perrins Ledge dental specimens. Based on observed variation of dental development between modern White populations and prehistoric Native American populations (Owsley and Jantz, 1983: AlQahtani *et al.*, 2014) Ubelaker's (1979) chart was preferred to that of AlQahtani *et al.* (2010) and was used to derive approximate age ranges. The commingled individuals were each identified using the same methods to derive the initial MNI as determined by Dr. Jane Buikstra during the original osteological assessment of the remains as previously discussed (Buikstra and Goldstein, 1973).

Table 3.2 Crown development age ranges for Perrins Ledge dental specimens.

Specimen	Tooth Sampled	Approximate Age Range of Crown Development
PLC11	Permanent First Molar (#30)	0 to 2.5 years
PLC12	Permanent First Molar (#19)	0 to 2.5 years
PLC13	Permanent First Molar (#14)	0 to 2.5 years
PLC14	First Premolar (#5)	0 to 2.5 years
PLC15	Permanent Second Molar (#15)	2.5 to 7 years
PLC16	Deciduous Second Molar (T)	0 to 9 months
PLC17	Permanent First Molar (#30)	0 to 2.5 years
PLC18	Deciduous Second Molar (T)	0 to 9 months

(Ubelaker, 1979)

Tissue Procurement and Processing

For all human and non-human specimens used in this study, of either bone or dental tissues, procurement was conducted using a diamond disc fitted to a Dremel® on medium low speed to minimize the potential for thermal abrasion induced recrystallization with contaminants prior to standard mechanical and chemical cleaning steps. Weights of the tissues procured from the Perrins Ledge cremains ranged from 0.01 to 0.14 grams and 0.0062 to 0.123 grams from the Newbridge, Apple Creek, and Newbridge faunal remains samples. Diamond discs were changed and cleaned with 70% alcohol between each specimen processed. Procured tissues were each sonicated dry and loose infiltrating soils were removed three times. Then samples were mechanically cleaned with a diamond bit fitted to a low speed micro engraver. For bone samples the entire outer surfaces were removed and for teeth all of the dentine and outermost surface was abrasively removed. The mechanical cleaning was observed under 100x bifocal microscopy with dual oblique lighting sources. Between specimens the diamond drill bit was sonicated in epure® water, then in a 1:1 solution of epure® water and 1M hydrochloric acid (HCl) for fifteen minutes, in epure® water again, then dried under a flow hood. Samples were then stored in microcentrifuge tubes and transported to continue processing at the Class 100 workstations in the Boston University, Department of Earth and Environment's geochemistry clean lab and TIMS facility.

Samples were transferred into capped Teflon beakers and sonicated for thirty minutes in milliQ® water, three times. MilliQ® rinse leachates were created and stored for each sample for later assessment of diagenetic signatures if necessary. The samples were uncapped and dried on a hotplate at 120º Celsius (ºC) under a flow hood. Once dried, samples were sonicated in weak acetic acid for fifteen minutes twice and rinsed with milliQ® water between baths. This is standard protocol for eliminating exogenous and external biogenic sources of strontium. Acetic acid leachates were also stored to assess diagenetic signatures at a later date if necessary. Bone samples were then ashed in lidded ceramic crucibles in a muffle oven for two hours at 1000ºC until completely calcined. Enamel and tooth specimens were dried down again and then both they and the bone samples were digested whole in 500ml of 3.5 N nitric acid (HNO_3) capped and placed on the hotplate (120ºC) overnight. Samples were then dried down and drawn up in 500ml of 5 N HNO_3 and transferred to microcentrifuge tubes and centrifuged at 1500rpms for five minutes before being loaded into pre-cleaned Teflon® ion exchange columns stored in 3.5 N HNO_3. Isolated strontium from the samples was then uncapped and dried down on the hotplate at 120ºC then re-dissolved in 2 µL 3.5 N nitric acid and loaded onto pre-outgassed single Re filaments with 2 µL of an emitter slurry (Ta_2O_2) and force dried at 0.6 amps then flash baked. Samples, procedural blanks, and 100 ng Sr standards (SRM-987) were analyzed with a high precision (250-800 cycles analyzed per sample) Triton Finnigan™ Thermal Ionization Mass Spectrometer. The average 87Sr/86Sr signature of eight analyzed SRM-987 standards was 0.710249 (± 0.000004; 2 RSE uncertainty).

The local signature was derived from combining the 2sigma ranges from the three baseline sites. In residential mobility research using strontium isotope ratios, the standard definition of an immigrant of a region is typically defined as an individual whose remains reflect strontium ratios that are beyond two standard deviations of the mean ratio of the regional baseline data with meaningful differences beginning at the fourth decimal place (Price *et al.*, 1994, 2002, 2012).

CHAPTER 4

RESULTS

Tables 4.1, 4.2, 4.3 and Figure 4.1 show the resulting mean signatures, standard deviation, and two-sigma range for each baseline site as well as the mean signatures for each of the Perrins Ledge samples. As previously mentioned, potential immigrants of a region are defined as those strontium ratios that fall beyond two standard deviations of the mean strontium ratio of each baseline site (Price *et al.*, 1994; 2002) and differences are recorded to the fourth decimal place (Price *et al.*, 2012; Slater *et al.*, 2014). The resulting calculated two-sigma ranges for each site are as follows: 0.70937 – 0.71018 for Apple Creek, 0.70935-0.71048 for Newbridge, and 0.70927-0.71025 for Carlin.

Results indicate that four of the 18 human remains samples from Perrins Ledge Crematorium fall within two standard deviations of the mean strontium ratio for at least one of the three baseline signatures and thus classify as local. Of those that classify as local the strontium signature derived from sample PLC09A is 0.710291 falling within the two-sigma range for Newbridge, the signature derived from sample PLC14A, 0.710355, also falls within the two-sigma range for Newbridge, the signature derived from PLC16A is 0.710228, falling within the two-sigma range for both Newbridge and Carlin, and the calculated signature for PLC18A is 0.710122, which falls within the two-sigma range for all three sites: Apple Creek, Newbridge and Carlin. Overall, only one of the 10 adult bone samples and one of the five adult enamel samples reflect signatures that classify as local and two of the three non-adults also classify as local.

Among those that classify as local are the two youngest children (PLC16A and PLC18A) who reflect signatures within the two-sigma range of at least two of the three baseline sites: the nine month old (PLC18A) classifies as a local within all three baseline site ranges and the four year old (PLC16A) falls within range of both Newbridge and Carlin. Only two signatures derived from adult remains (one enamel sample from a first premolar and one bone sample) classify as local, and both of those signatures are only within the range of Newbridge.

It should be noted that it was not possible to access the initial field excavation or osteological assessment notes at the time that the samples were collected to confirm which sex and age estimation belonged to each specimen as initially determined by Dr. Buikstra. Time constraints during data collection limited the ability to assess the cremains beyond determining the minimum number of individuals and identifying the non-adults by sorting dentition. Only five completely developed teeth could be isolated as belonging to separate adult individuals based on duplicate representation. It is assumed that the teeth belong to five of the ten individuals also represented by bone samples. With that said, the two adult signatures that classify as local for Newbridge may or may not be from a single individual.

If in the future the ages and sexes can be sorted out for the samples derived from these individuals then more information can be extracted from these results. Such as whether or not the two adult signatures (bone and tooth) represent a single individual, which would indicate that individual lived within the Newbridge region during dental development and during the last portion of their life.

Table 4.1. Strontium isotope (87/86) signatures of faunal remains from baseline sites.

Specimen	Tissue Type	87Sr/86Sr	2Sigma (±)	Site
151	Tooth	0.709542	0.000005	Apple Creek
425b	Tooth	0.709620	0.000004	Apple Creek
341B	Tooth	0.709928	0.000002	Apple Creek
600	Tooth	0.710023	0.000005	Apple Creek
F267c	Tooth	0.709763	0.000004	Apple Creek
117C	Bone	0.709739	0.000003	Newbridge
121C-W	Tooth	0.709517	0.000003	Newbridge
129C	Tooth	0.710170	0.000004	Newbridge
120B	Tooth	0.710167	0.000007	Newbridge
113B	Bone	0.709974	0.000006	Newbridge
101-3	Tooth	0.709916	0.000006	Carlin
101-3.1	Tooth	0.709510	0.000005	Carlin
9-1	Tooth	0.709927	0.000008	Carlin
101-3.2	Bone	0.709476	0.000003	Carlin
60-2B	Tooth	0.709971	0.000005	Carlin

Table 4.2 Mean strontium isotope (87/86) signatures and ranges for each baseline site.

Site Name	Smithsonian Trinomial	87Sr/86Sr Mean	2 sigma (±)	2 sigma Range
Apple Creek	11GE2	0.709775	0.000404192	0.709371 – 0.710179
Newbridge	11GE456	0.709913	0.000566901	0.709346 – 0.710480
Carlin	11C124	0.709760	0.000489798	0.709270 – 0.710250

Table 4.3 Strontium isotope signatures (87/86), tissue types, and the associated locality based on comparison with the three baseline site signature ranges.

Specimen	$^{87}Sr/^{86}Sr$	2 sigma	Tissue Type	Age Group	Locality
PLC01A	0.711520	0.000005	bone	Adult	Non-local
PLC02A	0.710621	0.000005	bone	Adult	Non-local
PLC03A	0.710916	0.000005	bone	Adult	Non-local
PLC04A	0.710640	0.000004	bone	Adult	Non-local
PLC05A	0.710778	0.000004	bone	Adult	Non-local
PLC06A	0.710757	0.000004	bone	Adult	Non-local
PLC07A	0.711023	0.000005	bone	Adult	Non-local
PLC08A	0.710728	0.000003	bone	Adult	Non-local
PLC09A	0.710291	0.000006	bone	Adult	Newbridge
PLC10A	0.711137	0.000004	bone	Adult	Non-local
PLC11A	0.711226	0.000004	enamel (M_1;#30)	Adult	Non-local
PLC12A	0.711143	0.000003	enamel (M_1;#19)	Adult	Non-local
PLC13A	0.711062	0.000003	enamel (M_1;#14)	Adult	Non-local
PLC14A	0.710355	0.000004	enamel (PM_1;#5)	Adult	Newbridge
PLC15A	0.711311	0.000005	enamel (M_2;#15)	Adult	Non-local
PLC16A	0.710228	0.000004	enamel (m_2;T)	~ 4 years old	Newbridge, Carlin
PLC17A	0.710528	0.000004	enamel (M_1;#30)	~ 7 years old	Non-local
PLC18A	0.710122	0.000006	enamel (m_2:T)	~ 9 months old	Apple Creek, Newbridge,

					Carlin

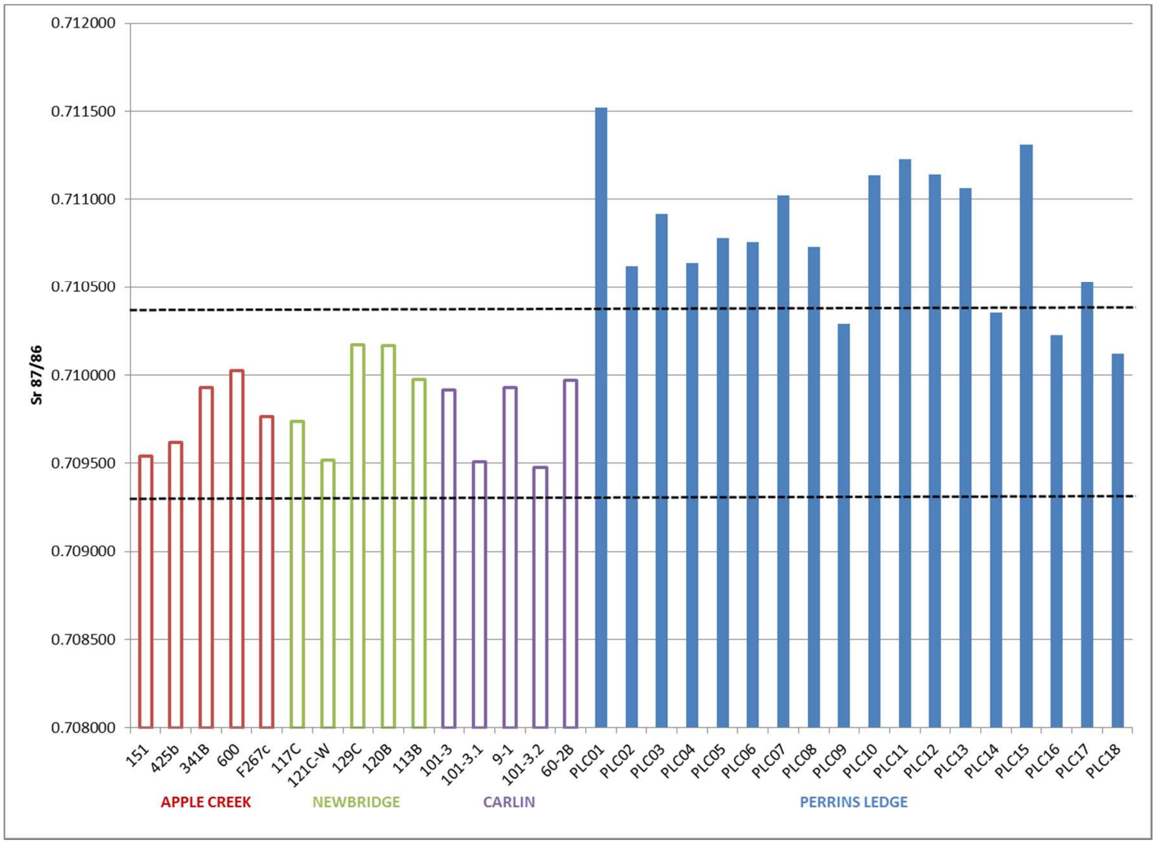

Figure 4.1 Strontium 87/86 signatures of each and Perrins Ledge samples. Dotted horizontal lines indicate the upper and lower signature limits for the "local" range derived from combining all three baseline sites.

CHAPTER 5

CONCLUSIONS AND DISCUSSIONS

Of the two hypotheses set forth by archaeologists specializing in the region regarding which groups may have utilized Perrins Ledge Crematorium the current data more firmly support the hypothesis that suggests the crematorium was used by non-sedentary hunter-gatherers from widely dispersed homesteads or hamlets to cremate their dead as proposed by Dr. Mark Schurr and Dr. Della Collins-Cook (2014). However, results of this study indicate that at least one of the 13 adult individuals and two of the three children reflect signatures fall within those ranges calculated as local from the three baseline sites (Apple Creek, Newbridge, and Carlin). Therefore, results also indicate that the other hypothesis, presented by Dr. Jane Buikstra and Dr. Lynn Goldstein (1973), that suggests Perrins Ledge Crematorium was used by groups inhabiting the local area, is also possible. Furthermore, these results do not rule out the possibility that Perrins Ledge could have been used by the local community to dispose primarily of non-locals. This study has demonstrated the utility of strontium isotope research in the contexts of cremation that includes a level of extensive fragmentation and organic destruction to the extent of calcination.

It is well understood that enamel is more resistant to diagenetic alteration than bone (Bentley, 2006). Recent work, however, has shown that once bone has reached thermal induced recrystallization (or calcination) it is as resistant, if not more so, than enamel (Snoeck *et al.*, 2015). At least three of the samples procured from the Perrins Ledge cremains appeared to have been calcined (PLC3, PLC5, PLC7 and PLC8). It is possible that more of the samples may have been calcined as well considering the identification of calcined bone can be easily obscured by soil staining over time (Buikstra and Goldstein, 1973). Additionally, the petrous portion of the temporal bone tends to remain more protected than outer regions of the cranium and post-cranial elements until fragmentation occurs. Heavy mechanical cleaning greatly reduced the sample size and removed outer layers of bone that may have been in contact with exogenous contaminants that can alter biogenic signatures. Lastly, considerable effort was made to chemically clean and rinse the samples following strict standard protocols used to eliminate diagenetic contamination and great care was taken to avoid procedural contamination.

Of great concern was the possibility of the carbonate rock of which the structure is constructed could alter the true biogenic signatures of the samples. However, the limestone of the lower Illinois River valley reflect reported 87/86 strontium isotope signatures that range from between 0.7076 to 0.7098 (Steuber *et al.*, 1993). If the limestone has contaminated the Perrins Ledge osseous cremains beyond the ability to be removed by chemical treatments, than the limestone values would have pulled the signatures down. Instead the signatures are quite high. It is possible that the limestone has pulled down some of the values but even so this still suggests that these signatures are non-locals.

As previously stated, the signature from the bone sample from one adult sample (PLC09A) falls within the upper range (0.70935-0.71048) for Newbridge at 0.71029. This suggests that this individual may have lived in this region for the later part of their life. All other bone samples from the other Perrins Ledge cremains fall beyond two standard deviations of any of the local baseline signatures suggesting that during the last decade of life these individuals did not live at those baseline habitation sites for long enough for the local strontium isotope signatures to develop within the mineral components of their bones. A fully developed first premolar from one individual reflects a signature that falls within the upper Newbridge range. The region sampled (mid-buccal aspect) from the crown of the first premolar of this individual (PLC14A) is known to develop between the ages of three and five (Hillson, 1996) suggesting that this individual may have lived near the Newbridge site during that period of development. As previously noted, without access to the excavation field notes it is not possible to determine whether these two tissue samples are from the same individual. However, the signatures from the two deciduous second molars representing the two youngest individuals (the four year old and nine month old) that reflect local signatures raise some interesting inquiries about possible familial relations.

These results imply that this crematorium was used to dispose of primarily non-local individuals. This is unusual for what could be considered a type of deviant burial that is situated on the upper bluffs where burials were most often reserved for productive members of local society (Charles and Buikstra, 1983) especially given that there were some pathological manifestations identified on these remains (Buikstra and Goldstein, 1973). The fact that some of the samples reflected signatures from within the local region suggests that some sort of possible interaction between two separate groups. Intragroup marriage is one suggestion.

It has recently been suggested that the Perrins Ledge Crematorium was possibly used as a processing site where cremains were intended to be eventually redeposited in a different cemetery elsewhere (Goldstein and Meyers, 2014). However, due to the fact that the remains from the initial burning episode were not removed for reburial leaves questions regarding this interpretation unanswered. If this site was used to dispose of non-locals, however, it is unlikely that their remains would be redeposited in any local cemeteries reserved for the local inhabitants of the area.

The applications of the present study may have utility in modern contexts where burned human remains or cremains are encountered in addition to those from prehistoric contexts. Globalization and mass distribution of modern food stuffs is a predicted confounding factor for efforts to reconstruct origins of individuals given that modern human populations seldom ingest the bioavailable strontium of the geographical region in which they live but rather from foods gathered and distributed from a variety of different geographical locations. It is suggested by the present author that temporal regional human population profiles can be developed as baseline data to replace the local faunal remains commonly used by archaeologists in residential mobility research. Regional population profiles could not, however, only consist of strontium isotope values due to the broadening variation between populations as an effect of the globalization of modern food stuffs, but would have to also include other trace element data and isotope values of other elements such as lead concentrations, oxygen and nitrogen isotope for example. In order to effectively differentiate between regional human population baselines by providing the means to create significant differences between groups, the population profiles would have to be defined by the combination of the calculated ranges of each of the data sets derived from the different trace elements and isotope signatures of various elements per population. In addition, the regional human population profiles would likely be altered over time with changes to mass distribution or the ebb and flow of the integration of local foodstuffs in the diet, and would thus require the recalculation of the profiles over time.

Current research is in the process to test the applicability of incorporating standard strontium isotope research into modern contexts with concerted effort focused on reconstructing the origins of those individuals that die attempting to cross the U.S.-Mexican borders (Juarez, 2008). Recent work has shown that strontium isotope ratios can be extracted from human hair samples (Tipple *et al.*, 2013). In light of the findings from the current study there is real potential to construct human population profiles of terrorist training camps to be compared with hair samples from questionable terrorists.

Considering the current movement in strontium isotope work and the aforementioned potential of baseline data derived from modern human population profiles constructed by multiple types of geochemical data sets, the broader implications of the present study are illuminated. The opportunity to reconstruct the origins of the thousands of individuals represented by highly fragmented calcined bone, from which DNA cannot be extracted, from the terrorist attacks on the world trade center in New York City on 9/11 become a realistic possibility in the future. Another potential application is the reconstructions the origins of the cremated individuals involved in the Tri-State Crematory scandal of 2002 in northwest Georgia. Again, the present study has demonstrated the utility and potential of strontium isotope analysis in the contexts of burned human remains.

APPENDIX A

BASELINE SPECIMENS FROM THE ISM:

SITE, SPECIES, CURATION, AND PROCURMENT DATA

IAS	Site Name	Specimen #	Type	Taxon	Common
11GE2	Apple Creek	425b	Adhering Soil	Ictidomys tridecemlineatus	13-lined Ground Squirrel
11GE2	Apple Creek	341b	Adhering Soil	Sylvilagus floridanus	Eastern Cottontail
11GE2	Apple Creek	F267c	Adhering Soil	Mustela vison	Mink
11GE2	Apple Creek	600-630-640 (P2)	Adhering Soil	Urocyon cinereoargenteus	Gray Fox
11GE2	Apple Creek	151	Adhering Soil	Urocyon cinereoargenteus	Gray Fox
11GE456	Newbridge	121C-W	Adhering Soil	Sciurus niger	Eastern Fox Squirrel
11GE456	Newbridge	129C	Adhering Soil	Ondatra Zibethicus	Muskrat
11GE456	Newbridge	120B	Adhering Soil	Sylvilagus floridanus	Eastern Cottontail
11GE456	Newbridge	113B	Adhering Soil	Microtus spp.	Vole
11GE456	Newbridge	117C	Adhering Soil	Scalopus aquaticus	Mole
11C124	Carlin	101-3	Adhering Soil	Marmota monax	Woodchuck
11C124	Carlin	101-3.1	Adhering Soil	Orozomys palustris	Marsh rice rat
11C124	Carlin	101-3.2	Adhering Soil	Sylvilagus floridanus	Eastern Cottontail
11C124	Carlin	60-2	Adhering Soil	Ondatra Zibethicus	Muskrat
11C124	Carlin	9-1	Adhering Soil	Marmota monax	Woodchuck

Metrics (mm)	**Raw Wt.** (g)	**procured Wt.** (mg)	**portion procured**	**Source**
26x14x3	0.28	66.6	Whole Mand. Incisor	
	0.0005			
59x15x5	1.85	81.1	Front molar superior 1/2	
	0.002			
35x7x5	1.6	6.2	Buccal Molar	
	0.0014			
42x23x7	3.7	6.7	Lingual Molar (small back molar)	
	0.0029			
46x17x4	4	8.2	Buccal Premolar	
	0.0829			
21x10x5	0.5	28.2	Whole molar	CAA
	0.0023			
12x4x3	0.22	14	interproximal surface	CAA
	0.0004			
7x4x2	0.14	7.5	interproximal surface of molar	CAA
	0.0056			
13x3x3	0.04	18.2	femur shaft frag	CAA
	0.001			
25x5x1	0.14	90.6	lateral 2/3rds	CAA
	0.0011			
46x5x4	1.25	6.8	labial surface	CAA/IL DOT
	0.0012			
15x5x5	0.11	19.4	portion of incisor	CAA/IL DOT
	0.0005			
41x6x3	0.55	122.5	distal 1/3rd shaft	CAA/IL DOT
	0.001			
43x4x4	0.46	9.1	labial surface	CAA/IL DOT
	0.0003			
46x5x4	1.1	6.8	labial surface	CAA/IL DOT
	0.0052			

Accession #	Project	Year	Int. Prov.	Material	Bag label
2010-0207	CAA #200	Unknown		Faunal - Mammal	"White Hall Mammal"
2010-0207	CAA #200	Unknown		Faunal - Mammal	"White Hall Mammal"
2010-0207	CAA #200	Unknown		Faunal - Mammal	"White Hall Mammal"
2010-0207	CAA #200	Unknown		Faunal - Mammal	"Gray Fox"
2010-0207	CAA #200	Unknown		Faunal - Mammal	"Gray Fox"
2010-0218	#276	1974-1975	F-Levels 121-124	Fauna	"NWB 121 2 of 2"
2010-0218	#276	1974-1975	F-Levels 126-130	Fauna	"NWB 129 1 of 2"
2010-0218	#276	1974-1975	F-Levels 110-120	Fauna	"NWB 120"
2010-0218	#276	1974-1975	F-Levels 110-120	Fauna	"NWB 113B" and "NWB 113"
2010-0218	#276	1974-1975	F-Levels 110-120	Fauna	"NWB 117 1of2" and "NWB 117c"
1995-0214	FAP38/CAA #272	1972	F#Range 2-101	FAUNA	"1995-214, Carlin Site, Feature 101"
1995-0214	FAP38/CAA #272	1972	F#Range 2-101	FAUNA	"1995-214, Carlin Site, Feature 101"
1995-0214	FAP38/CAA #272	1972	F#Range 2-101	FAUNA	"1995-214, Carlin Site, Feature 101"
1995-0214	FAP38/CAA #272	1972	F#Range 2-101	FAUNA	"1995-214, Carlin, Feature 60"
1995-0214	FAP38/CAA #272	1972	F#Range 2-101	FAUNA	"1995-214, Carlin, Feature 9"

Box	Associated Dates
1 of 1	A.D. 450-750 (Parmalee *et al.*, 1972)
1 of 1	A.D. 450-750 (Parmalee *et al.*, 1972)
1 of 1	A.D. 450-750 (Parmalee *et al.*, 1972)
1 of 1	
1 of 1	
12 of 13	A.D. 400-700 (Emerson *et al.*, 2000)
11 of 13	A.D. 400-700 (Emerson *et al.*, 2000)
3 of 13	A.D. 400-700 (Emerson *et al.*, 2000)
3 of 13	A.D. 400-700 (Emerson *et al.*, 2000)
2 of 13	A.D. 400-700 (Emerson *et al.*, 2000)
1 of 3	A.D. 400-700 (Emerson *et al.*, 2000)
1 of 3	A.D. 400-700 (Emerson *et al.*, 2000)
1 of 3	A.D. 400-700 (Emerson *et al.*, 2000)
1 of 3	A.D. 400-700 (Emerson *et al.*, 2000)
1 of 3	A.D. 400-700 (Emerson *et al.*, 2000)

APPENDIX B

PERRINS LEDGE SPECIMENS DATA

SPECIMEN	WEIGHT (gm)	TISSUE / PORTION SAMPLED
PLC 01	0.0360	Bone: posterior inferior the internal acoustic meatus
PLC 02	0.0187	Bone: medial inferior the int. acoustic meatus
PLC 03	0.0239	Bone: inferior int.ac.mts.
PLC 04	0.0232	Bone: inferior int.ac.mts.
PLC 05	0.0348	Bone: inferior int.ac.mts.
PLC 06	0.0320	Bone: inferior int.ac.mts.
PLC 07	0.0328	Bone: inferio-medial int. ac. mts.
PLC 08	0.0924	Bone: inferio-medial int. ac. mts.
PLC 09	0.0446	Bone: inferio-medial int. ac. mts.
PLC 10	0.0305	Bone: inferior int. ac. mts
PLC 11	0.1281	Tooth: disto-lingual cusp of R. mand. M1
PLC 12	0.1329	Tooth: disto-lingual cusp of L. mand. M1
PLC 13	0.1043	Tooth: lingual surface
PLC 14	0.1251	Tooth: buccal surface
PLC 15	0.0319	Tooth: buccal (nat. frag)
PLC 16	0.0117	Tooth: distal 2/3 of lingual surface
PLC 17	0.0381	Tooth: distal 1/2 of lingual surface
PLC 18	0.0158	Tooth: buccal surface of fragment

ELEMENT/PORTION
right petrous portion fragment of temporal bone
right petrous portion of temporal bone fragment
right petrous portion fragment of temporal bone
right petrous portion fragment of temporal bone
right petrous portion fragment of temporal bone
right petrous portion of temporal bone fragment
right petrous portion fragment of temporal bone
right petrous portion fragment of temporal bone
right petrous portion fragment of temporal bone
right petrous portion fragment of temporal bone
fragmented permanent right mandibular first molar crown (#30)
permanent left mandibular first molar fragment (#19)
permanent left maxillary first molar crown fragment (#14)
buccal surface of the permanent right maxillary first premolar (#5)
buccal enamel fragment from the permanent left maxillary second molar (#15)
deciduous right mandibular second molar (T)
right mandibular first molar (permanent in development = Root 3/4)(#30)
mesial 1/2 fragment of a deciduous right mandibular second molar crown (deciduous in development = cr3/4 to crc)(T)

APPENDIX C

STRONTIUM SIGNATURE RESULTS

Sample	87/86 MEAN	2Sigma	Taxon	Tissue Type	Site
151	0.709542	0.000005	fox	tooth	Apple Creek
425b	0.709620	0.000004	squirrel	tooth	Apple Creek
341B	0.709928	0.000002	rabbit	enamel	Apple Creek
600…	0.710023	0.000005	fox	tooth	Apple Creek
F267c	0.709763	0.000004	mink	enamel	Apple Creek
117C	0.709739	0.000003	mole	bone	Newbridge
121C-W	0.709517	0.000003	fox	tooth	Newbridge
129C	0.710170	0.000004	muskrat	tooth	Newbridge
120B	0.710167	0.000007	rabbit	tooth	Newbridge
113B	0.709974	0.000006	Vole	bone	Newbridge
101-3	0.709916	0.000006	woodchuck	tooth	Carlin
101-3.1	0.709510	0.000005	rice rat	tooth	Carlin
9-1	0.709927	0.000008	woodchuck	tooth	Carlin
101-3.2	0.709476	0.000003	rabbit	bone	Carlin
60-2B	0.709971	0.000005	muskrat	tooth	Carlin
PLC01A	0.711520	0.000005	human	bone	Perrins Ledge
PLC02A	0.710621	0.000005	human	bone	Perrins Ledge
PLC03A	0.710916	0.000005	human	bone	Perrins Ledge
PLC04A	0.710640	0.000004	human	bone	Perrins Ledge
PLC05A	0.710778	0.000004	human	bone	Perrins Ledge
PLC06A	0.710757	0.000004	human	bone	Perrins Ledge
PLC07A	0.711023	0.000005	human	bone	Perrins Ledge
PLC 08A	0.710728	0.000003	human	bone	Perrins Ledge
PLC09A	0.710291	0.000006	human	bone	Perrins Ledge
PLC10A	0.711137	0.000004	human	bone	Perrins Ledge
PLC11A	0.711226	0.000004	human	M1	Perrins Ledge
PLC12A	0.711143	0.000003	human	M1	Perrins Ledge
PLC13A	0.711062	0.000003	human	M1	Perrins Ledge
PLC14A	0.710355	0.000004	human	pm1	Perrins Ledge
PLC15A	0.711311	0.000005	human	M2	Perrins Ledge
PLC16A	0.710228	0.000004	human S.A.	m2	Perrins Ledge
PLC17A	0.710528	0.000004	human S.A.	M1	Perrins Ledge
PLC18A	0.710122	0.000006	human S.A.	m2	Perrins Ledge

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